Queen Mary

UNIVERSITY OF LONDON

MSc ASTROPHYSICS

ASTRONOMICAL TECHNIQUES ASTM042

Date: 14 MAY 2001 **Time:** 14:30

TIME ALLOWED: 90 MINUTES

Answer all parts of Section A and one question from Section B.

Each section is given equivalent weighting.

Use a SEPARATE answer book for EACH question.

You are permitted to use an electronic calculator in this examination. Please state on your answer book the name and type of machine used.

DATA

The following physical constants and data may be assumed:

Speed of light	$c = 3.00 \times 10^{8}$ m s^{-1}
Planck's constant	$h = 6.63 \times 10^{-34}$ J s
Boltzmann's constant	$k_B = 1.38 \times 10^{-23}$ J K^{-1}
Rest mass energy of the electron	$m_ec^2 = 0.511$ MeV
Definition of the Jansky	1 Jy = 10^{-26} W m^{-2} Hz^{-1}

SECTION A - this section is compulsory

a) Define the term Noise Equivalent Power (NEP).

b) Explain why there is an inevitable compromise between spectral resolution and sensitivity in any measurement of electromagnetic radiation.

c) A p-type semiconductor has an energy gap ΔE between the top of the valence band and the acceptor impurity levels. Sketch the energy band diagam and write down the formula for the cut-off wavelength.

d) Why is a Dicke switched receiver necessary for detecting weak radio sources?

e) Sketch the continuum spectra for blackbody, free-free and synchrotron radiation.

f) Explain what is meant by the term "seeing" and mention briefly its consequences. Explain briefly why ground-based adaptive optics systems can provide improved sensitivity for point source observations.

g) What are the two main sources of spurious output pulses in a photomultiplier detector? How does pulse height discrimination allow the signal-to-noise ratio to be improved?

h) Over what portions of the electromagnetic spectrum are astronomical observations impossible from the ground?

i) Derive the Plate Scale Equation relating size of the image in the focal plane of a telescope to the angle subtended by the source on the sky.

j) Describe briefly, with the aid of a diagram, the operation of a single pixel (MOS capacitor) of a CCD array.

SECTION B - answer one question only from this section

Question B1

Show that the output from a simple two element, one dimensional, spatial radio interferometer is proportional to:

$$f(\theta)\left[1 + \cos\left(\frac{2\pi x\theta}{\lambda}\right)\right]$$

where $f(\theta)$ is the source brightness distribution function, θ is the zenith angle, x is the spatial separation of the antennae and λ is the wavelength of observation.

Determine the form of the receiver output for a phase-switched system and explain why such a system is preferred for most observations.

How is the output from such an interferometer used to give the source brightness distribution?

Explain the technique of de-convolution. How could it improve the final image quality?

Question B2

a) At X-ray and γ-ray wavelengths, electromagnetic radiation interacts with matter by the photoelectric effect, the Compton effect, or electron-positron pair production. Describe briefly each of these processes, and indicate the photon energy regimes in which they are important. Explain why, if accurate measurement of the incident photon energy is required, absorption by the photoelectric effect rather than the Compton effect may be preferred.

b) A beam of monochromatic γ-ray photons is absorbed in a scintillation detector by the Compton effect. The maximum total energy of the scattered electron, corresponding to "head-on" Compton scattering is measured at 1.022 MeV. Apply the laws of conservation of energy and momentum to the encounter and thus find the energies, in eV, of the incident and scattered photons. Verify that the change in wavelength is $\Delta\lambda = 2h/(m_e c)$.

End of Examination